The Great Basin Naturalist

PUBLISHED AT PROVO, UTAH, BY
BRIGHAM YOUNG UNIVERSITY

ISSN 0017-3614

VOLUME 54 | 31 JULY 1994 | NO. 3

Great Basin Naturalist 54(3), © 1994, pp. 193–203

HABITAT REQUIREMENTS FOR *ERIGERON KACHINENSIS*, A RARE ENDEMIC OF THE COLORADO PLATEAU

Loreen Allphin[1] and Kimball T. Harper[2]

ABSTRACT.—*Erigeron kachinensis* is a rare endemic of the Colorado Plateau in southeastern Utah. This perennial composite grows in small, isolated populations at seeps and alcoves arising along canyon walls in Cedar Mesa Sandstone substrates. Characteristics of six *Erigeron kachinensis* sites in Natural Bridges National Monument, San Juan County, Utah, were studied to determine habitat requirements for this species. Sites were analyzed with respect to geology, soil chemistry, physical properties, and vegetational characteristics. The alcoves studied were very saline, often with soil surfaces covered with a white crust of salt. Living cover was enhanced by perennially moist soils, diminished amounts of solar radiation, soil salinity, and above-average amounts of available soil phosphorus. Kachina daisy vegetative growth appears to be favored by these same abiotic factors. The most commonly associated plant species on *E. kachinensis* sites were *Aquilegia micrantha, Calamagrostis scopulorum, Zigadenus vaginatus*, and *Erigeron kachinensis*. These species and the daisy accounted for more than 75% of the total living cover in the alcoves studied. A principal components analysis procedure was developed for evaluating site suitability for *Erigeron kachinensis*. This daisy has been successfully introduced to a site selected using that model.

Key words: Erigeron kachinensis, *Colorado Plateau, critical habitat.*

The Kachina daisy (*Erigeron kachinensis* Welsh & Moore) was discovered and named in 1968 (Welsh and Moore 1968). It is a rare perennial composite of the Colorado Plateau region of Utah and Colorado. The species grows in small, isolated populations at seeps and alcoves arising along the edges of deep canyons in these areas. No discussions of the habitat requirements of this species have appeared in the literature. The Kachina daisy was proposed as "endangered" by the U.S. Fish and Wildlife Service on 16 June 1976 (U.S. Department of Interior 1975, 1976). Later proposals downgraded the original recommendation to "threatened" status for the species (U.S. Department of Interior 1988). Currently, the Kachina daisy is listed by the U.S. Fish and Wildlife Service as a category 2 species, i.e., a species for which more information is needed before assigning final designation (endangered, threatened, or sensitive).

In 1984 an effort was launched to document locations of all populations of the Kachina daisy and their size in Natural Bridges National Monument (NBNM), San Juan County, Utah. In that study eight populations were recorded (Fagan 1984). In 1988 and 1989 the National Park Service selected four of the eight populations

[1]Department of Biology, University of Utah, Salt Lake City, Utah 84112.
[2]Department of Botany and Range Science, Brigham Young University, Provo, Utah 84602. Please address all reprint requests to this author.

for a 2-year monitoring program. Relative cover of Kachina daisy plants in these populations was reported to vary by almost 60% between years (Belnap 1988, 1989). Belnap's report to the National Park Service called for protection and further research to determine whether the observed declines in population size were due to natural fluctuations in temperature and precipitation or to more permanent stresses in the physicochemical environment. It was also considered possible that the species was poorly adapted to the associated environmental conditions.

Since this species appears to be restricted to seeps and alcoves, typically along a single seepline within a canyon, there is concern for its preservation. If drought caused seeplines occupied by this species to dry up, many populations could be eliminated. As tourism increases in the canyon regions of southeastern Utah, so does the threat of human impacts on rare species. Tourists hiking in canyon bottoms look to shady alcoves as refuge from the hot summer sun. Many of the seeps and alcoves contain small, prehistoric Anasazi Indian ruins that also attract tourists.

At the outset of this study, the Kachina daisy was known only from NBNM and a population in Montrose County, Colorado. With but few known populations confined to uncommon site situations, resource managers were concerned that the species might be vulnerable to extinction. These concerns resulted in the research presented in this manuscript. Our objectives were to determine habitat requirements for the Kachina daisy and to develop a management strategy for preservation of the species. If habitat requirements can be established accurately, potentially occupiable sites for the species could be identified and new populations established.

STUDY AREA AND METHODS

The Kachina daisy grows in seeps and natural alcoves in the Cedar Mesa Sandstone of White and Armstrong canyons in NBNM between 1680 and 1890 m elevation. The Cedar Mesa Formation, deposited in Permian time (Hintze 1975), is a coarse-grained, porous sandstone that stores considerable water within its massive deposits. In thickness the Cedar Mesa Formation varies from 500 to 1200 m. Its depth is at a maximum in the Elk Ridge and NBNM area. Alcoves where the daisy grows are developed in Cedar Mesa Sandstone immediately above the Halgaito Formation.

The Halgaito Formation lies below the Cedar Mesa Sandstone. It is a part of the Cutler group, as is the Cedar Mesa Sandstone. The Halgaito Formation consists of mostly reddish brown siltstone, sandstone, and thin beds of limestone. It varies from 400 to 500 m in thickness (Hintze 1975). Where percolating water encounters finer-textured lamina in the Cedar Mesa Sandstone, it accumulates and moves laterally until it reaches the faces of vertical walls of deep, narrow drainage channels that cross outcrops of the Cedar Mesa Formation.

A survey of canyons surrounding NBNM for *Erigeron kachinensis* was initiated under a contract with the Bureau of Land Management. In addition to populations known in NBNM (Welsh et al. 1987), the Kachina daisy has now been found on lands administered by the Bureau of Land Management (Allphin and Harper 1991). Populations are known in Fish, Arch, White, and Birch canyons; from Dark Canyon Primitive Area in San Juan County, Utah; and from the lower portion of Coyote Wash, Montrose County, Colorado (Welsh et al. 1987, Allphin and Harper 1991).

Six of the eight populations in NBNM were chosen for detailed study based on accessibility and contrasting site characteristics (Fig. 1). The six study sites vary in respect to aspect, soil moisture, and soil salinity. These sites include two west-facing, two south-facing, and two north-facing alcoves. All study sites are located along the 1768-m (5800-ft) contour line. Study sites were monitored in June 1990, 1991, and 1992. It is pertinent to note that all sites occur in alcoves or seeps except site 2, which occupies a slope kept moist by seepage from an alcove directly above.

At each site individual daisy plants were selected for study using the point center quarter method (Cottam and Curtis 1956) along a 100-m transect. These individuals were marked with numbered aluminum tags held at their bases with galvanized nails. The tags facilitated later relocation of individual plants.

Several abiotic characteristics were described by taking composite soil samples from the six study populations. A minimum of five composite soil samples were taken per alcove. From those soil samples, soil water content,

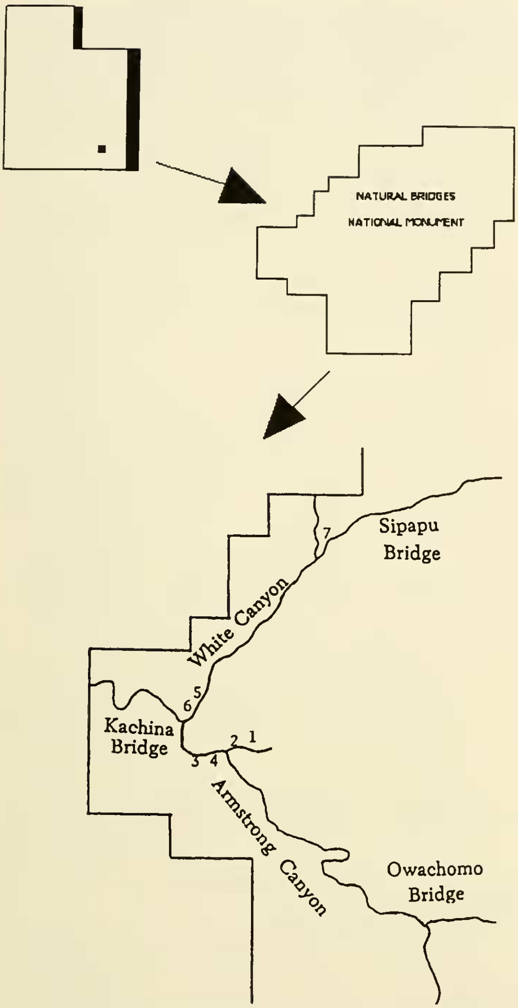

Fig. 1. Location of Kachina daisy sites monitored in this study and a site where Kachina daisy plants have been transplanted in Natural Bridges National Monument, San Juan County, Utah (# 1 = north-facing alcove A, # 2 = north-facing alcove B, # 3 = south-facing alcove A, # 4 = south-facing alcove B, # 5 = west-facing alcove A, # 6 = west-facing alcove B, and # 7 = transplant site).

percentage of coarse material (diameter >2 mm), soil texture, percentage of sand, percentage of organic matter, pH, electrical conductivity, and concentrations of the biogenic elements (P, K, Ca, Mg, Na, Cu, Fe, Mn, and Zn) were estimated. All soil analyses were made by personnel of the Soil and Plant Analysis Laboratory, Department of Agronomy and Horticulture, Brigham Young University, and all analytical methods were based on those recommended by Black et al. (1965). Soil texture was determined with a hydrometer. Reaction (pH) of soil was taken with a glass electrode on a saturated soil-water paste. Organic matter was quantitated by digestion with 1.0 N potassium dichromate. Phosphorus was determined with the iron-TCA-molybdate method on a soil extract taken with .2 N acetic acid. Exchangeable bases were freed from the soil with 1.0 N ammonium chloride. Ion concentrations in extract solutions were estimated by atomic absorption.

Vegetational data were also collected at each study site in NBNM. Frequency and cover of individual species and percentage of total living plant cover were determined for each study site using a 100-cm^2 quadrat. In addition, vegetative and floral characteristics of 600 tagged plants were recorded at each visit. Variables evaluated for each plant include number of rosettes, crown diameter, leaf length (average for two longest leaves), number of leaves, number of flower heads, number of flowers per head, and number of filled seeds per flower head. The number of filled seeds per head was determined by harvesting mature heads in June and observing whether seeds were filled with mature embryos.

Soil data from the various study sites were analyzed by one-way analysis of variance (ANOVA) for significant differences between sites. The least significant difference multiple range test of Snedecor and Cochran (1967) was used to determine significant differences among individual means for each site. Vegetational data were analyzed using a two-way analysis of variance for both site and year. Once again the multiple range test was used to identify significant differences among means for all measured vegetative characteristics among the six alcoves. ANOVAs were performed using the STATA statistical package (Computing Resource Center 1992).

To determine the effect of the abiotic environment on vegetative growth in alcoves containing the Kachina daisy, abiotic environmental variables were regressed against total living cover, species richness, and Kachina daisy characteristics. Since no significant regression correlations could be found between abiotic environmental and individual daisy characteristics, a whole-plant response index was determined using standardized values for various daisy characteristics among the six alcoves.

Vegetative daisy characteristics were standardized by setting the largest value for each variable at 100 and expressing the value for that parameter at each study site as a percentage of the maximum value. These standardized values were summed for each of the alcoves to give an integrated estimate of overall plant response. A reproductive daisy response was also measured as number of filled seeds based upon total number of heads produced by individual daisy plants and number of flowers per head. Both simple and multiple linear regressions were performed to evaluate the response of various plant variables to the following abiotic factors: moisture content, salinity, and available phosphorus in the soil. All regressions were performed using the STATA statistical package (Computing Resource Center 1992).

Composite soil samples were also taken from populations found on lands administered by the Bureau of Land Management. Species found in association with the Kachina daisy were recorded for each population. An alcove found near Sipapu Bridge within NBNM contained no Kachina daisies but did harbor several of the species commonly associated with the daisy (Fig. 1). This location was considered a potential introduction site for the Kachina daisy. A composite soil sample from the site was analyzed to further assess its suitability for this daisy. Mean soil characteristics from sites on BLM lands and the potential transplant site were analyzed by multiple range comparison with the six study alcoves. Principal components analysis (Pielou 1984)) was used to further evaluate the suitability of the Sipapu Bridge site for the Kachina daisy using all environmental variables in a multivariate analysis. Soil characteristics considered in that analysis included phosphorus (mg/kg), electrical conductivity, average soil moisture (June), and average soil temperature (June). Total species richness at each site was also used in the principal components analysis. The principal components analysis was conducted using the SAS statistical package (SAS Institute, Inc. 1993).

Demography and reproductive biology of the Kachina daisy are addressed in greater detail in another manuscript. Results presented in this paper will deal only with information concerning habitat of the species.

RESULTS

Physical Environment

Soils in alcoves occupied by Kachina daisy are sandy loams ranging from 70.4 to 89.6% sand (Table 1). They are very alkaline with pH values of 7.8–9.1. All alcoves studied develop a crusty layer of white salt on the soil surface during the drier part of the year. Data demonstrate that *E. kachinensis* is very tolerant of saline conditions. Electroconductivity of soils from the study sites ranges from 6 to 31 mmhos/cm. The average electrical conductivity value for soils from the six alcoves was 13.6 mmhos/cm. Conductivity values over 8 mmhos/cm are considered high enough to restrict yield of most crop plants (Richards 1954).

Soil temperatures (at ~1 cm depth) at sites occupied by the daisy are cool, ranging from 13.2 to 15.8° C in June (Table 1). Soils in alcoves are always cooler than surrounding soils because they receive less sunlight and stay reasonably moist. Soil temperatures in June vary only slightly among sites, with higher temperatures occurring at sites receiving greater amounts of direct sunlight.

Percent soil water content in occupied alcoves varies from 5.8 to 25.6% of dry weight in mid-June (Table 1). NBNM receives most of its precipitation from November through March (Fig. 2; Brough et al. 1987). Water accumulates in the sandstone during these months but is available for plant growth in all seasons because of the large reservoir of water held in the sandstone.

Alcoves 3 and 6 have the wettest soils (Table 1). This is perhaps related to the fact that these alcoves receive only about 1 h of direct sunlight per day in June. Site 2 has the driest soil. It occurs on a slope outside and directly below an alcove seep. In addition, it receives the most sunlight daily and is farther from a seepline than other study sites. It faces north and is exposed to sunlight only during afternoon hours.

All alcoves considered had similar levels of phosphorus (7.5–11.4 mg/kg). They also had high values for potassium, calcium, magnesium, and sodium (Table 1). ANOVA and multiple range tests demonstrate that soils at alcove 3 differ significantly from those of other alcoves. Alcove 3 soils have significantly higher electrical conductivity, a greater percentage of Na saturation, and significantly higher levels of potassium, magnesium, and sodium. This alcove also has significantly lower levels of manganese and calcium than the other alcoves studied. These differences may be related to

TABLE 1. Chemical and physical characteristics of soil from alcoves that support *Erigeron kachinensis* at Natural Bridges National Monument (1–6), San Juan County, Utah. Each value represents an average of five samples from each alcove. Alcove 7 represents potential transplant site in Natural Bridges National Monument. Column 8 represents a mean of five alcoves in surrounding canyons on BLM land. Means followed by the same letter do not differ at the $p < .05$ level of significance. Soil temperature and moisture values represent average conditions for mid-June in summers of 1990–92.

	Alcove no.							
	1	2	3	4	5	6	7	8
Elevation (m)	1768	1768	1768	1768	1768	1768	1768	1859
Aspect (deg.)	302(WNW)	328(NNW)	160(SSE)	197(SSW)	252(WSW)	225(SW)	250(WSW)	191(SSW)
Hr. direct sunlight/day in June	5.0	5.75	1.0	4.5–5.25	4.6	0–1.5	—	—
Texture	sandy lm	loamy snd	sandy lm	sandy lm	sandy lm	sandy lm	sandy lm	sandy lm
Sand (%)	89.6 a	76.7 a	80.3 a	70.4 a	80.1 a	71.7 a	73.3 a	66.8 a
pH	8.6 c	8.8 cd	9.1 d	8.6 c	7.9 ab	7.8 a	8.6 c	8.2 b
EC (mmhos/cm)	13.1 bc	17.1 c	31.1 d	7.6 ab	6.9 a	6.0 a	—	9.8 b
Ave. soil temp (C)	14.1 a	15.8 bc	13.9 a	15.1 b	13.9 a	13.2 a	13.5 a	16.4 c
Soil moisture (%)	12.3 b	5.8 a	18.4 c	12.2 b	12.7 b	25.6 d	13.2 b	12.3 b
Organic matter (%)	1.8 b	1.1 a	2.0 bc	2.2 c	0.8 a	1.6 b	—	—
Skeletal mtl. (% by wt.)	12.1 ab	15.1 b	17.2 b	6.8 a	7.2 ab	7.2 ab	—	—
Essential elements								
P (mg/kg)	11.4 a	10.7 a	9.8 a	10.9 a	7.5 a	8.0 a	9.3 a	10.2 a
K (mg/kg)	197.0 ab	229.5 b	640.2 c	153.0 a	80.4 a	82.0 a	—	—
Ca (mg/kg)	9590 c	7886 b	6758 a	10508 d	10884 d	10282 cd	—	—
Mg (mg/kg)	2498 a	2754 a	11904 b	2030 a	870 a	730 a	—	—
Na (mg/kg)	649.0 ab	822.4 b	2535.0 c	322.6 ab	126.7 a	127.4 a	—	—
Cu (mg/kg)	0.48 ab	0.36 a	0.56 b	0.32 a	0.36 a	0.60 b	—	—
Fe (mg/kg)	1.8 b	0.96 a	1.4 ab	1.9 b	1.9 b	2.2 b	—	—
Mn(mg/kg)	6.8 c	6.0 bc	1.8 a	6.6 c	2.4 a	4.8 b	—	—
Zn (mg/kg)	0.60 b	0.44 a	0.72 b	0.88 c	0.96 c	0.72 b	—	—
Na saturation (%) of exchangeable bases	2.5 b	3.5 bc	6.0 c	1.2 ab	0.5 a	0.6 a	—	—

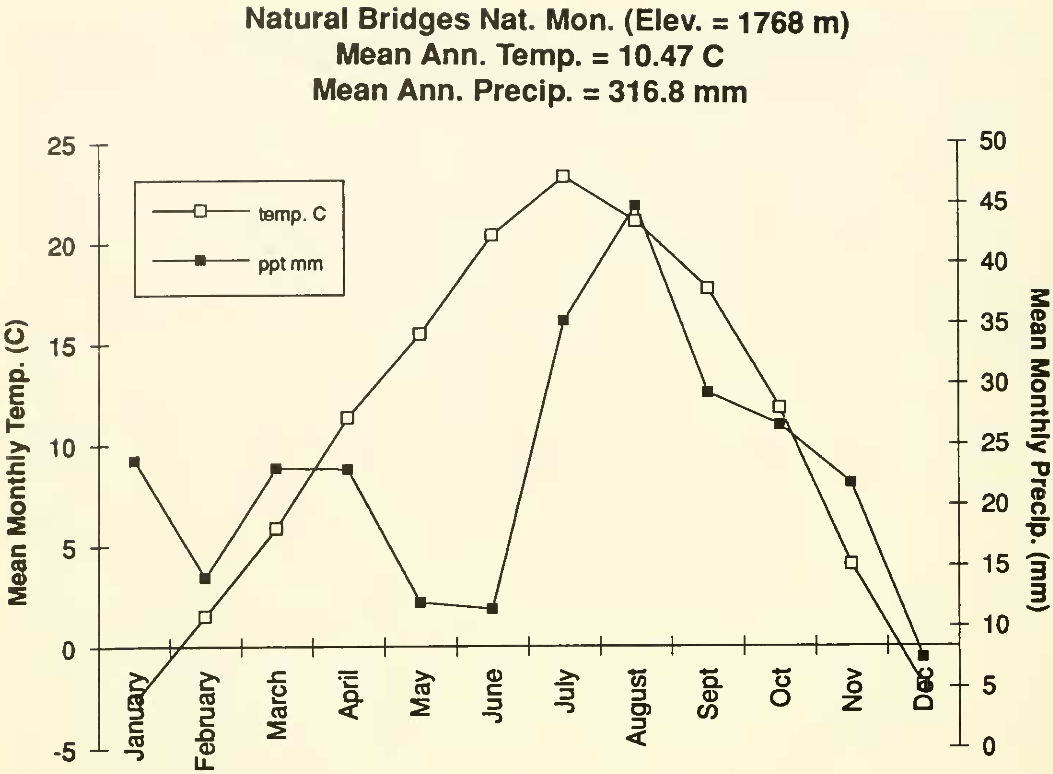

Fig. 2. Climatic diagram for Natural Bridges National Monument. Data represent average values for the period 1987–91.

the fact that the floor of alcove 3 is developed from a reddish brown siltstone/sandstone probably of the Halgaito Formation rather than the Cedar Mesa Sandstone. Even though alcove 3 soils differ from those of other alcoves, the daisy population is thriving and seems unaffected by soil differences.

Kachina Daisy Characteristics

Characteristics of the average daisy in each of the alcoves studied intensively are noted in Table 2. The average number of rosettes per individual varied from 1.4 to 2.5 among the six sites. Statistical differences among the sites with respect to the number of rosettes per daisy plant are noted in Table 2. Alcoves 3 and 4 supported the largest plants, while the smallest plants grew in alcoves 2 and 5.

Average clump diameter for the Kachina daisy ranged from 3.6 to 7.3 cm among the study sites. Alcove 2 plants had the smallest diameters, which perhaps reflects the fact that alcove 2 had the driest soil observed among the alcoves (Table 2).

Average leaf lengths ranged from 1.9 to 3.6 cm among the six study sites. Alcove 2 plants had the smallest leaves observed. Average number of leaves per plant ranged from 9.9 to 23.6 among the study sites. As might have been expected, the number of leaves per plant was smallest for alcove 2 (Table 2).

Statistical differences seen among characteristics of plants from these alcoves reflect the fact that alcoves were chosen for apparent differences in moisture, aspect, and direct sunlight. Plants from alcoves that receive little direct sunlight (sites 3, 4, and 6; Table 1) had larger leaves and clump diameters than plants from alcoves 1 and 5, which received more sunlight. The amount of sunlight could also be expected to affect soil moisture, which should also produce differences in vegetative characteristics.

Biotic Associates

Ecological and vegetational characteristics showed no significant differences among the years of study (1990–92); thus, data given in

TABLE 2. Ecological and vegetational characteristics and average characteristics of 100 randomly selected Kachina daisy plants at each of the six alcoves shown in Table 1. All values are based on data taken during field seasons 1990–92. Means followed by the same letter do not differ significantly at $p < .05$.

	Alcove no.					
	1	2	3	4	5	6
Total living cover (%)	42.5 c	17.8 a	45.5 c	62.4 d	18.1 a	37.7 b
Species richness*	6.3 a	5.3 b	4.7 c	9.0 d	4.3 c	7.0 e
Ave. # spec./ 100-cm² quad.	2.8 d	1.8 b	1.6 ab	2.6 d	1.4 a	2.1 c
			Characteristics of *E. kachinensis*			
No. rosettes/plant	1.6 a	1.4 a	2.5 c	2.1 b	1.6 a	1.9 b
Plant diam. (cm)	4.8 b	3.6 a	6.2 c	7.3 d	4.4 b	6.6 c
Leaf length (cm)	2.7 b	1.9 a	2.5 b	3.6 c	2.1 a	3.4 c
No. leaves/plant	13.2 b	9.9 a	23.6 d	22.2 d	13.5 b	17.3 c
Plant response indices**	492 (veg.) 225 (rep.)	355 (veg.) 202 (rep.)	540 (veg.) 253 (rep.)	605 (veg.) 290 (rep.)	387 (veg.) 226 (rep.)	604 (veg.) 226 (rep.)
			Characteristics of prevalent species			
Erigeron kachinensis frequency (%)***	66.7 d	44.0 b	38.7 a	54.7 c	53.3 c	72.0 e
Ave. cover (%)	6.3 b	2.9 a	7.5 c	7.0 c	3.4 a	6.0 b
No. plants/m²	15.1	12.7	6.1	15.7	7.9	27.4
Aquilegia micrantha frequency (%)***	73.3 d	56.0 c	57.3 c	26.7 b	8.0 a	56.0 c
Ave. cover (%)	18.2 d	8.7 b	16.2 c	2.9 a	2.5 a	17.3 cd
Calamagrostis scopulorum frequency (%)***	40.0 d	16.0 b	32.0 c	40.0 d	9.3 a	41.3 d
Ave. cover (%)	4.6 b	2.7 a	16.8 d	15.0 d	2.2 a	8.1 c
Zigadenus vaginatus frequency (%)***	53.3 c	33.3 b	30.7 b	61.3 d	68.0 d	2.7 a
Ave. cover (%)	10.6 c	2.97 b	4.7 b	22.4 d	10.0 c	0.05 a

*Species richness = number of species per 25-m transect.
**Plant response indices = summed, relativized values for both vegetative (veg.) and reproductive (rep.) characteristics of the Kachina daisy (see text for details).
***Frequency = percentage of 100-cm² sampling quadrats placed per 25-m transect that included this species.

Table 1 are means based on results for the three summers. Total living cover at locations that support *E. kachinensis* ranged from 17.8 to 62.4% in the six alcoves studied intensively (Table 2). Most living cover was contributed by *E. kachinensis*, *Aquilegia micrantha*, *Calamagrostis scopulorum*, and *Zigadenus vaginatus*. Frequency and cover values for those species are reported in Table 2.

Several species were found to occur regularly with the Kachina daisy in both Natural Bridges National Monument and lands managed by the Bureau of Land Management in that part of San Juan County, Utah (Table 3). Considering all known locations for the Kachina daisy in San Juan County, Utah, only four species were found to coexist with it at 75% or more of the occupied sites. Those species were *Aquilegia micrantha*, *Calamagrostis scopulorum*, *Cirsium calcareum*, and *Zigadenus vaginatus*. These species are thus good indicators of habitat suitable for the Kachina daisy.

Three abiotic variables were found to have a significant effect on total living cover in the

TABLE 3. Species associated with *Erigeron kachinensis* at all (100+) sites of occupancy on Bureau of Land Management Lands and the six study sites at Natural Bridges National Monument, San Juan County, Utah.

*Aquilegia micrantha*****
*Calamagrostis scopulorum*****
*Cirsium calcareum*****
*Zigadenus vaginatus*****
*Epipactus gigantus****
*Helianthella microcephala****
*Heterotheca villosa****
Adiatum capillus var. *veneris***
*Carex aurea***
*Castilleja linariifolia***
*Cirsium rydbergii***
*Gilia subnuda***
Hymenopapus filifolius var. *cinereus***
*Mimulus eastwoodii***
*Senecio multilobatus***
*Swertia radiata***
Galium multiflorum var. *coloradoense**
Gilia congesta var. *palmifrons**
Habenaria sparsiflora var. *sparsiflora**
*Juncus arcticus**
*Leptodactylon pungens**
*Solidago sparsiflora**
Aster chilensis~
Comandra unbellata~
Penstemon watsonii~
Ranunculus cymbalaria~
Trees and shrubs
*Pinus edulis****
*Rhamnus betulaefolia****
*Cercocarpus intricatus***
*Juniperus osteosperma**
*Pinus ponderosa**
Amelanchier utahensis~
Clematis ligusticifolia~
Mahonia fremontii~
Populus fremontii~
Salix exigua~

****>75% of Kachina daisy populations.
***50–75% of Kachina daisy populations.
**25–50% of Kachina daisy populations.
*5–25% of Kachina daisy populations.
~<5% of Kachina daisy populations.

six alcoves: soil water content, soil salinity, and available phosphorus. Results of regression analyses between these three important environmental variables and total living plant cover, integrated vegetative response of the Kachina daisy, and species richness are reported in Table 4.

Salinity was negatively related to total living cover and species richness in simple regression analyses. Total available phosphorus was significantly related to total living cover in the alcoves. When soil salinity and soil water content were considered together in multiple regression, they were significantly correlated with total living plant cover. Partial correlation coefficients show that soil water content accounts for significantly more of the variation in total living plant cover in the model than does soil salinity [% total cover = 3.6(% water content) +.015 (EC)]. The combined effects of soil moisture, soil salinity, and available phosphorus gave the strongest multiple correlation coefficient obtained with total living cover. In this study increased soil moisture appeared to reduce the effect of salinity on plants in the alcoves and permitted good growth of most adapted species in soils of high salinity.

Vegetative response of the daisy was found to be significantly influenced by percent soil moisture (Table 4), but salinity and phosphorus were not significantly correlated with vegetative response. When salinity and moisture are combined in multiple linear regression, a positive, but not significant, influence is shown for vegetative growth. By adding phosphorus to salinity and moisture in multiple regression analysis, the correlation coefficient became statistically significant. Not only do these three abiotic variables affect total cover of all species, but they also appear to be important for vegetative growth of the Kachina daisy. In contrast, reproductive response of the daisy was not found to be significantly influenced by any abiotic variable or combination of variables. Kachina daisy reproduction by seed thus appears to be tolerant of the differences observed for important abiotic environmental variables in this study.

The Sipapu Bridge site (site 7, which did not support a population of the Kachina daisy) was found to be environmentally similar to the six Kachina daisy study sites and sites that supported the daisy on lands administered by the BLM (Table 1). Results of a principal components analysis that considered all environmental variables simultaneously confirm this finding (Fig. 3). The Sipapu Bridge site falls among the alcoves that supported Kachina daisy in the diagram depicting the principal components analysis results.

DISCUSSION

Characteristics of habitat suitable for the Kachina daisy can be predicted from the results of this study. Sites favorable for daisy growth have sandy loam soils, saline soils (13–14 mmhos/cm on average), and a perennial

TABLE 4. Influence of three important environmental variables (soil water content, soil salinity, and available phosphorus) on total living plant cover, integrated vegetative response, and species richness. Vegetative daisy response is based upon summed relativized values for leaf length, crown diameter, number of rosettes per plant, number of leaves per plant, total daisy cover, daisy density, and daisy frequency. Reproductive daisy response represents number of filled seeds per flower head, considering total number of heads per plant and total number of flowers per head. Significance level is given next to each *r*-value.

Independent variable(s)	Dependent variables: % living cover	Daisy response: Vegetat.	Daisy response: Reprod.	Species richness
	r-value for simple regression			
Soil water content (%)	.15 NS	.85**	.50 NS	.11 NS
Salinity (EC)	–.79*	.09 NS	.42 NS	–.75*
Available P (mg/kg)	.75*	.05 NS	.03 NS	.14 N
	Multiple *r*-value for multiple regression			
Soil water content and salinity (EC)	.95**	.75 NS	.43 NS	.79 NS
Soil water content, salinity (EC), and available P (mg/kg)	.99**	.98**	.60 NS	.86 NS

**Regression significant at $p < .05$ level of significance.
*Regression significant at $p < .10$ level of significance.
NS Regression not significant.

source of water. Occupied soils are alkaline to strongly alkaline. Kachina daisies require perennially moist, cool soils along seeplines. However, these areas typically have large overhangs that sometimes provide too much shade for adequate growth. Therefore, daisies commonly grow on the outside perimeter of the alcove or sometimes directly below the alcove, as seen at site 2. Vegetative features of the plant at sites that typically receive little direct sunlight are typical of those of shade plants: large, thin leaves and elongated stems. Soil water content appears to buffer the effect of high salinity on vegetative growth within the alcoves (Table 4). Above-average levels of soil phosphorus appear to enhance growth of the Kachina daisy (Table 4). Available soil phosphorus averaged about 9.5 mg/kg at sites occupied by Kachina daisy in this study. Habitat occupied by Kachina daisy also supports several other characteristic species. The most common species associated with the daisy include *Aquilegia micrantha*, *Calamagrostis scopulorum*, *Cirsium calcareum*, and *Zigadenus vaginatus* (Table 3).

Three abiotic variables appear to have the greatest influence on total living plant cover in alcoves and vegetative Kachina daisy growth, i.e., soil water content, soil salinity, and available soil phosphorus (Table 4). These variables obviously act in concert to influence plant growth in the alcoves. For instance, soil water content has a strong, positive effect on vegetative growth of the daisy, but the positive effect is amplified when both water and soil phosphorus are considered in the analysis (Table 4). Although these variables are important to vegetative growth in the alcoves, they appear to have minimal influence on reproduction in the Kachina daisy.

Since we observed no significant variation in Kachina daisy populations in the six alcoves studied over a 3-year period, it is questionable whether the large year-to-year variations in relative cover of this species reported by Belnap (1988, 1989) are real. Belnap's results may be attributable to the taking of samples at different locations within the alcoves in different years. Our study included three of the same alcoves as those sampled by Belnap (our alcoves 1, 5, and 6), but we could detect no significant differences in either water flow or plant community composition among years of observation. The discrepancy between Belnap's results and ours probably relates to sampling design. Our samples were always taken at the

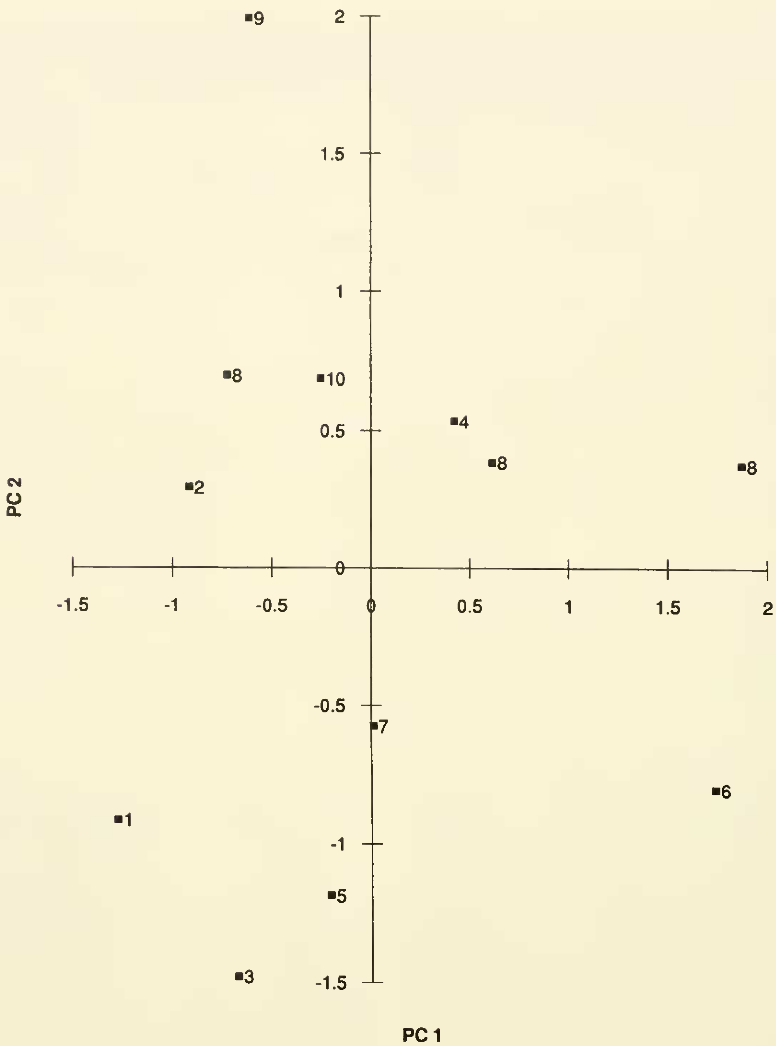

Fig. 3. Plot of the first two components of soil samples from the six Kachina daisy study sites in NBNM (1–6), the Sipapu Bridge transplant site (7), and Kachina daisy sites on BLM land (8–10, three site 8 alcoves in Fish Canyon, site 9 in White Canyon, site 10 in Arch Canyon). See Table 1 and text for explanation.

same permanently marked points in each year of study, while Belnap sampled at random within the 2 years of analysis.

The U.S. Park Service has encouraged attempts to transplant the Kachina daisy into what may be suitable habitat in NBNM, but until the results reported here became available there were no criteria for evaluating the suitability of a site for the species. Since an alcove at the Sipapu Bridge at NBNM appeared to fall within the range of environmental suitability for this daisy (Table 1, Fig. 3), we made experimental transplants of the species into that alcove. Presently, no known natural populations of Kachina daisy occur near this site. The site is a west-facing alcove along the 1768-m (5800-ft) contour level. The habitat resembles other Kachina daisy sites in that salinity is high and many species occur on the site that are known to consistently grow with the daisy. Six daisies were transplanted in the alcove in summer 1991. Four of the six survived to summer 1992. Approximately 200 plants were taken from a site to be destroyed by road construction in 1992 and transplanted at the Sipapu alcove; at least 100 of these plants survived and some even flowered in 1993. Based on these favorable results, the Park Service is now considering seeding the Kachina daisy in other suitable alcoves within NBNM.

The validity of the suite of characters given above as descriptors of suitable Kachina daisy habitat is further supported by the fact that many new locations for the species were located on BLM lands in the region by searching for habitats and associated species closely similar to the combination of characteristics noted above.

We note that others have collected an *Erigeron* from rock crevices on Elk Ridge, San Juan County, Utah, that is morphologically indistinguishable from populations in this report. However, the habitats associated with specimens from Elk Ridge rock faces and those associated with alcove daisies of the deep canyons of NBNM are extremely different in respect to elevation, soil moisture, solar radiation, soil salinity, and associated species. Genetic analysis will be required to determine how closely allied these two taxa are.

The populations found on BLM land as a result of this study demonstrate that the Kachina daisy is more common than once believed. The species is well adapted to alcoves of the Cedar Mesa Formation, but it is apparently unable to occupy any other habitats in the deep canyon environments. It is imperative that managers protect alcoves with perennial seep lines in the Cedar Mesa Formation from disturbance. Trails should not be permitted to intrude into the alcoves, and camping within the alcoves should be forbidden.

ACKNOWLEDGMENTS

This study was supported in part by grants from the Bureau of Land Management, the Utah Native Plant Society, and Brigham Young University. The U.S. Park Service provided housing and living expenses for the primary author during periods of field research. We extend special thanks to Dr. Lee G. Caldwell for his assistance with computer analyses and statistical designs used for evaluation of data on which this article is based.

LITERATURE CITED

ALLPHIN, L., AND K. T. HARPER. 1991. Survey of the Grand Gulch Primitive Area for *Erigeron kachinensis*. Report submitted to Bureau of Land Management, U.S. Department of Interior, October 1991.

BELNAP, J. 1988. Kachina daisy survey. Report submitted to Resource Management Division, Canyonlands National Park, U.S. Department of Interior, 13 July 1988.

______. 1989. Kachina daisy survey. Report submitted to Resource Management Division, Canyonlands National Park, U.S. Department of Interior, summer 1989.

BLACK, C. A., D. D. EVANS, J. L. WHITE, L. E. ENSMINGER, AND F. E. CLARK, EDS. 1965. Methods of soil analysis, part 1: physical and mineralogical properties, including statistics of measurement and sampling. American Society of Agronomy, Inc., Madison, Wisconsin. 770 pp.

BROUGH, C. R., D. L. JONES, AND D. J. STEVENS. 1987. Utah's comprehensive weather almanac. Publishers Press, Salt Lake City, Utah. 401 pp.

COMPUTING RESOURCE CENTER. 1992. STATA reference manual: release 3. 5th edition. Santa Monica, California.

COTTAM, G., AND J. T. CURTIS. 1956. The use of distance measures in phytosociological sampling. Ecology 37: 451–460.

FAGAN, D. 1984. Report on status of Kachina daisies in Natural Bridges National Monument. Submitted to Resource Management Division, Canyonlands National Park, U.S. Department of Interior, 19 May 1984.

HINTZE, L. F. 1975. Geologic history of Utah. BYU Geology Studies, Vol. 3, Pt. 3. Brigham Young University Press, Provo, Utah. 162 pp.

PIELOU, E. C. 1984. The interpretation of ecological data. John Wiley and Sons, New York. 263 pp.

RICHARDS, L. A., ED. 1954. Diagnosis and improvement of saline and alkali soils. USDA Agricultural Handbook No. 60. 160 pp.

SAS INSTITUTE, INC. 1993. SAS user's guide: statistics. SAS Institute, Inc., Cary, North Carolina.

SNEDECOR, G. W., AND W. G. COCHRAN. 1967. Statistical methods. 6th edition. Iowa State University Press, Ames. 593 pp.

U.S. DEPARTMENT OF INTERIOR, FISH AND WILDLIFE SERVICE. 1975. Review of *Erigeron kachinensis* as an endangered species. Federal Register 40: 27880.

______. 1976. Proposal that *Erigeron kachinensis* be listed as endangered. Federal Register 41: 24524–24572.

______. 1988. Endangered Species Act of 1973 as amended through the 100th Congress. U.S. Fish and Wildlife Service, Washington, D.C. 45 pp.

WELSH, S. L., AND G. MOORE. 1968. Plants of Natural Bridges National Monument. Proceedings of the Utah Academy of Sciences, Arts, and Letters 45: 220–248.

WELSH, S. L., N. D. ATWOOD, L. C. HIGGINS, AND S. GOODRICH. 1987. A Utah flora. Great Basin Naturalist Memoirs No. 9. Brigham Young University Press, Provo, Utah. 894 pp.

Received 28 January 1993
Accepted 1 March 1994